

A STUDY OF WATER QUALITY INDEX ASSESSMENT OF GROUND WATER AND POND WATER IN SIRSAKALA VILLAGE OF BHILAI-3, CHHATTISGARH, INDIA

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ABSTRACT

This paper mainly focusing on to assess the water quality index (WQI) of ground water and pond water of sirsakala village of bhilai-3, Chhattisgarh, India. In the present study nine water samples of Bhilai-3, were collected from the different locations of sirsakala village during Oct.2012–Sept. 2013 and fifteen water quality parameters have been considered such as pH, EC, TDS, turbidity, hardness, Fluoride, calcium, magnesium, chloride, DO, BOD, sulphate, alkalinity, nitrate, and COD were studied and compared with the standard values prescribed by ICMR and BIS. The water is characterized by very high contents in excess of the maximum prescribed limit of Indian Council for Medical Research and Bureau of Indian Standard. However, most of the water samples did not have high concentrations of the toxic contaminants. The present investigation revealed that the some of the ground and pond water samples of source sirsakala village of Bhilai-3 are not suitable for domestic, bathing, drinking purpose and they needs some treatment before consumption and it is also needs to be protected from contamination.

KEYWORDS: Pond Water, Ground Water, Water Quality Index, Water Quality Standard and Physiochemical Analysis

INTRODUCTION

Water is one of the most indispensable resources and is the elixir of life. Life is not possible on this planet without water (Ghosh M.K., et al 2013). Ground water is a good source of fresh water available on the earth. It is the important renewable resource having several inherent advantages over surface water (Singh S. et al., 2013). Safe drinking water is a fundamental human need and it is an important factor that determines the physical and social health of the people (Bullard et al., 1978) inferred that polluted surface water always results in an unhealthy socio-economic environment. Effluents generated by industries are sources of pollution. Contaminated air, soil, and water by Industrial effluents are associated with disease burden like fluosis, diarrhea, dysentery, typhoid, dengue, malaria, hepatitis, skinning, cancer, gastroenteritis, liver and intestinal infection etc. Chemical contamination of drinking water may not cause time intake may be fatal for human health and this could be reasons for the current shorter life expectancy in Chhattisgarh state and in the country (Ghosh M.K., et al. 2013). Hence, quality index assessment of water is important to assess the quality of groundwater and surface water in any rural and urban areas that influences the suitability for drinking, domestic, bathing, irrigation and industrial needs. The importance of groundwater in drinking and in other uses, its environmental aspects such as contamination transport have been significantly studied.

Water quality index assessment describes the overall quality of the water based on several water quality variables. The quality of water may depend on geology of particular area and also vary with depth of water table and seasonal changes and is governed by the extent and composition of the dissolved salts depending upon source of the salt and soil-surface environment. The objective of water quality index assessment is to give information to mankind regarding the

quality of a particular water body for multipurpose usages. In general, water quality index assessment method gets data from several water quality variables into a mathematical equation and rates out the quality of water in terms of a number (Yogendar et al.,2008).The present paper reports results of the study of ground and surface waters in the year of Oct.2012-Sept.2013 sirsakala village Bhilai-3, Chhattisgarh, India

OBJECTIVES OF THE STUDY

The objective of the present work is to emphasize on the quality of a water body based on quality index assessment to describe about its suitability for human consumption and other commercial purposes.

STUDY AREA

ArcGIS (version 9.0) software has been used for the present study to locate the current study area. Sirsakala village an industrial area is a part of Bhilai-3 situated on the central of large fertile plain of Chhattisgarh. It is situated between 21.21°N Latitude and 81.38°E Longitude, with a height of 452M (1,483 ft.) on the Howrah-Mumbai NH-6 road. It is 25-30 km far away from its state main city raipur . Surface water and ground water is a main source of water for the industrial areas of Bhilai . The surface and ground water quality of sirsakala is continuously degraded due to industrial activities and soils of the nearby fields are also being affected. Therefore, we have decided to analyze its surface and ground water. The study area of the proposed work is shown in the Figure 1a, 1b and 1c.



Figure 1a: Locations of Chhattisgarh in India

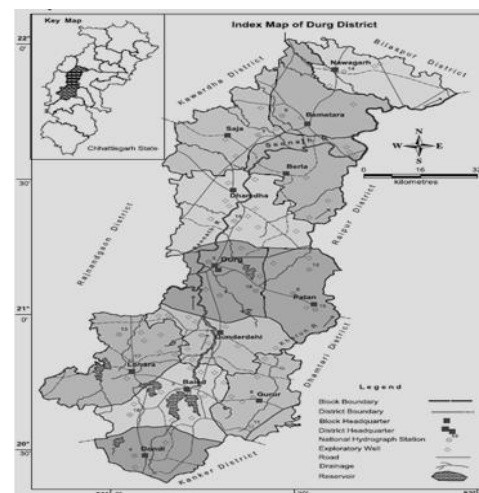


Figure 1b: Locations of Durg in Chhattisgarh

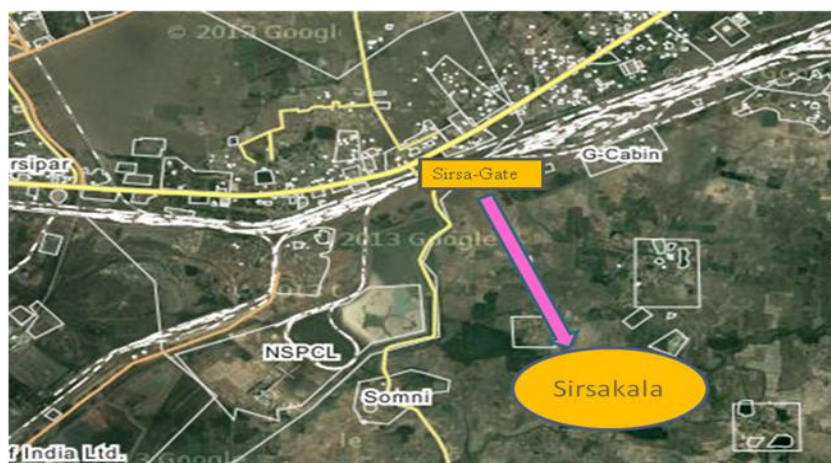


Figure 1c: Locations of Surface Water and Ground Water Sites Sirsakala Village Bhilai-3 of Durg District in Chhattisgarh

MATERIALS AND METHODS

In present investigation eight water samples taken from ten pond water and fifteen ground water samples were collected from the different sites of sirsakala village during Oct.2012-Sept 2013 and taken in pre-cleaned 1litre polyethylene bottles. The samples after collection were immediately placed in dark boxes and processed within 6 h of collection. The analysis of water was done using procedure of standard methods.

Table 1: Chemical Parameters and their Methods Used (APHA-1995)

Parameters	Methods
Temperature ⁰ C	Thermometric method
pH	Systronics pH meter
EC	Systronic Conductivity Meter-304
Fluoride	Ion Selective
TDS	HM digital meter TDS-3
Turbidity	Digital Nephlo-Turbid meter-132
Hardness	EDTA-Titration
Calcium	Elico flame photometer
Magnesium	Elico flame photometer
Chloride	Argentometric titration,
DO	Chemiline DO meter CL-930
BOD	BOD-Merck BOD meter
Sulphate	Turbidimetric Method
Alkalinity	Titration with acid HCl
Nitrate	UV spectrophotometer
COD	Spectroquanta Merck COD meter

Water Quality Index (WQI)

The concept of indices to represent gradation in water quality was first proposed. It indicates the quality by an index number, which represents the overall quality of water for any intended use. It is defined as a rating reflecting the composite influence of different water quality parameters on the overall quality of water. The WQI has been calculated from the point of view of the suitability of pond water for human consumption(Mishra et al.2001). Table 2.

Table 2: Water Quality Classification Based on WQI Value

Class	WQI Value	Water Quality Status
I	Less than 25	Excellent Water
II	26-50	Good Water
III	51-75	Poor Water
IV	76-100	Very poor Water
V	More than 100	Unsuitable for drinking

The WQI has been calculated by using the standards of drinking water quality recommended by the World Health Organization (WHO), Bureau of Indian Standards (BIS) and Indian Council for Medical Research (ICMR). The calculation of WQI was made using a weighted arithmetic index method given below (Brown et al., 1972) in the following steps.

Calculation of Water Quality Index

For the calculation of WQI, selection of parameters has great importance. Since selection of too many parameters might widen the water quality index, and the importance of various parameters depends on the intended use of water, sixteen physicochemical parameters, were used to calculate the WQI. The calculation of WQI was made using a weighted arithmetic mean method(Inayathulla et al.,2013) given in the following steps.

Calculation of Quality Rating (qn)

Now Let us we consider n be water quality parameters where the quality rating or sub index (qn) corresponding to the n th parameter is a number reflecting the relative value of this parameter in the polluted water with respect to its standard permissible value. The value of qn is calculated using the following expression.

$$qn = 100[(Vn - Vi) / (Sn - Vi)] \quad (1)$$

Where, qn = quality rating for the n^{th} water quality parameter.

Vn = Observed value of the n^{th} parameter at a given sampling station.

Sn = standard permissible value of n^{th} parameter

Vi = ideal value of n^{th} parameter in pure water.

In most cases $Vi = 0$ except in certain parameters like $pH=7.0$ (natural water) and permissible value $pH=8.5$ (polluted water) similarly for dissolved oxygen= 14.6mg/L and Fluoride= 1.0 mg/L etc., Calculation of quality rating for pH , Fluoride and DO as below.

$$q_{pH} = 100 (V_{pH} - 7.0) / (8.5-7.0), q_F = 100 (V_{pH} - 1.0) / (1.5-1.0),$$

$$\text{and } q_{DO} = 100 (V_{DO} - 14.6) / (5.0-14.6)$$

Calculation of Unit Weight (Wn)

Calculation of unit weight (Wn) for various water quality parameters are inversely proportional to the recommended standards for the corresponding parameters.

$$Wn = K / Sn \quad (2)$$

Where, Wn = unit weight for n^{th} parameter

Sn = standard value for n^{th} parameters,

K = proportionality constant and is given as (Kalavathy et al., 2011)

$$K = 1/[1/S_1 + 1/S_2 + \dots + 1/S_n]$$

Here the unit weight(Wn) values in the present study are taken study are taken from (Krishnan J.S.R et al.1995).

Calculation of WQI

WQI is calculated from the following equation as below

$$WQI = \sum_{n=1}^n q_n w_n / \sum_{n=1}^n w_n \quad (3)$$

Table 3: Drinking and Bathing Water Standards, Recommending Agencies and Unit Weights

S. No	Parameters	Standard Permissible Value (Sn)	Recommended Agency	Unit Weight(Wn)
1	pH	8.5	ICMR/BIS	0.083
2	EC($\mu\text{s/cm.}$)	300	ICMR	0.002
3	Turbidity	10	BIS	0.01
4	TDS	500	ICMR/BIS	0.001
5	Fluoride	1.5	BIS	0.471
6	Hardness	300	ICMR/BIS	0.002

Table 3: Contd.,

7	Calcium	75	ICMR/BIS	0.009
8	Magnesium	30	ICMR/BIS	0.024
9	Chloride	250	ICMR	0.003
10	DO	5	ICMR/BIS	0.141
11	BOD	5	ICMR	0.100
12	Sulphate	150	ICMR/BIS	0.005
13	Alkalinity	120	ICMR	0.006
14	Nitrate	45	ICMR/BIS	0.016
15	COD	20	ICMR	0.025

* All the parameters value are expressed in mg/l except pH, Turbidity (NTU)

**Table 4: Seasonal Variations of the Physico-Chemical Parameters Water Body During the Study Period
(All the Parameters Value are Expressed in mg/l Except pH, Turbidity(NTU))**

Parameters	Seasons	Sampling Stations									Average
		Gw1	Gw2	Gw3	Gw4	Gw5	Gw6	Pw1	Pw2	Pw3	
pH	Rainy	7.29	7.54	7.23	7.51	7.21	7.10	7.08	7.04	7.61	7.29
	Winter	9.03	9.45	8.99	8.54	8.31	8.73	7.35	7.30	7.12	8.31
	Summer	9.32	9.89	10.20	8.71	8.96	10.5	7.54	7.58	7.80	8.94
EC(μ S/cm)	Rainy	765	823	932	956	810	789	352	453	410	698.8
	Winter	798	876	987	969	894	810	550	510	521	768.3
	Summer	989	1004	989	902	932	874	710	669	703	863.5
Turbidity (NTU)	Rainy	1.8	2.1	1.3	2.5	3.1	2.7	14.3	12.1	14.2	6.011
	Winter	2.1	2.8	3.1	1.9	3.4	2.9	14.1	13.1	11.3	6.077
	Summer	2.9	3.4	3.3	3.9	3.7	3.5	15.4	15.3	15.1	7.388
TDS(mg/L)	Rainy	480	510	498	430	410	490	294	312	352	419.5
	Winter	365	389	456	478	486	526	475	480	470	458.3
	Summer	668	715	710	698	770	654	598	510	528	650.1
Hardness (mg/L)	Rainy	210	254	198	231	267	276	152	176	198	218.0
	Winter	178	276	234	312	321	387	190	179	256	259.2
	Summer	345	412	432	476	490	453	365	367	340	408.8
Fluoride (mg/L)	Rainy	0.21	0.26	0.28	0.07	0.18	0.86	0.48	0.89	0.65	0.431
	Winter	0.37	0.29	0.87	0.90	0.54	0.97	1.0	0.57	0.76	0.696
	Summer	1.87	1.67	1.32	1.21	1.14	1.02	1.10	1.07	1.09	1.276
Calcium (mg/L)	Rainy	56	48	55	47	59	51	46.81	41	42.5	49.59
	Winter	58	50	49	53	48	57	49	52	51	51.88
	Summer	69	57	52	63	57	65	58	64	69	61.55
Magnesium (mg/L)	Rainy	12.12	10.3	11.1	12.75	14	13	8.52	9.2	7.9	10.96
	Winter	11.2	11.8	14	15	17	16	10	10.4	8.2	12.62
	Summer	13.3	14.6	19.1	18.3	18.1	18.6	18.9	17.4	16.2	17.16
Chloride (mg/L)	Rainy	53	57	59	67	76	73	41.49	82	78	65.16
	Winter	57	59	68	87	84	95	85	95	87	79.66
	Summer	202	251	143	223	99	245	109	235	234	193.4
DO (mg/L)	Rainy	5.59	6.10	5.63	5.90	5.73	5.26	5.32	5.37	5.49	5.598
	Winter	4.9	5.6	5.2	5.7	5.1	4.6	5.8	5.3	5	5.244
	Summer	5.2	5.12	5.3	5.23	5.75	5.43	5.23	5.67	5.0	5.325
BOD mg/L)	Rainy	6.4	5.7	6.8	6.1	6.6	5.2	6.9	7.1	7.3	6.455
	Winter	6.9	7.1	7.04	7.05	7.34	7.65	7.56	7.23	7.42	7.254
	Summer	5.2	5.6	5.7	6.3	6.7	6.1	6.7	6.2	6.1	6.066
SO ₄ (mg/L)	Rainy	36	34	32	31	36	40	42.34	41.2	42	37.17
	Winter	41	40	43	47	41	42.3	43.1	45.1	43.1	42.84
	Summer	67	56	58	62	63	68	69	64	61.2	63.13
Alkalinity (mg/L)	Rainy	98	111	102	92	89	84	112	124	119	103.4
	Winter	187	190	213	209	275	198	253	215	227	218.5
	Summer	243	310	342	267	297	307	357	312	342	308.5
Nitrate (mg/L)	Rainy	19	21	18	16	25	20	22	28	25	21.55
	Winter	23	26	28	31	30	37	27	34	32	29.77
	Summer	37	31	39	41	46	42	48	40	43	40.77

Table 4: Contd.,

COD (mg/L)	Rainy	2	6	1	5	3	9	7	4	8	5.000
	Winter	6	4	7	2	10	14	9	11	13	8.444
	Summer	12	14	17	14	11	15	13	18	20	14.88

Where Symbols stand for GW= Ground water, PW= Pond water

Table 5: Calculation of Water Quality Index in Rainy Season

Rainy Season						
S. No.	Parameters	Standard Value (S_n)	Unit Weight (W_n)	Observed Values	Quality Rating (q_n)	Weighted ($W_n q_n$)
1	pH	8.5	0.083	7.29	19.330	1.604
2	EC	300	0.002	698.8	232.93	0.465
3	Turbidity	10	0.010	6.011	60.110	0.601
4	TDS	500	0.001	419.5	83.900	0.083
5	Hardness	300	0.471	218.0	72.666	34.222
6	Fluoride	1.5	0.002	0.431	-113.80	-0.227
7	Calcium	75	0.009	49.59	66.120	0.595
8	Magnesium	30	0.024	10.96	36.533	0.876
9	Chloride	250	0.003	65.16	26.064	0.078
10	DO	5	0.141	5.598	93.770	13.221
11	BOD	5	0.100	6.455	129.10	12.910
12	SO ₄	150	0.005	37.17	24.780	0.123
13	Alkalinity	120	0.006	103.4	86.166	0.516
14	Nitrate	45	0.016	21.55	47.888	0.766
15	COD	20	0.025	5.000	25.000	0.625
$\sum W_n = 0.898$ $\sum q_n W_n = 66.454$						
$WQI = \sum q_n W_n / \sum W_n = 74.00$						

Table 6: Calculation of Water Quality Index in Winter Season

Winter Season						
S. No.	Parameters	Standard Value (S_n)	Unit Weight (W_n)	Observed Values	Quality Rating (q_n)	Weighted ($W_n q_n$)
1	pH	8.5	0.083	8.31	87.33	7.248
2	EC	300	0.002	768.3	256.10	0.512
3	Turbidity	10	0.010	6.077	60.77	0.607
4	TDS	500	0.001	458.3	91.66	0.091
5	Hardness	300	0.471	259.2	86.40	40.694
6	Fluoride	1.5	0.002	0.696	-60.80	-0.121
7	Calcium	75	0.009	51.88	69.17	0.622
8	Magnesium	30	0.024	12.62	42.06	1.009
9	Chloride	250	0.003	79.66	31.864	0.095
10	DO	5	0.141	5.244	97.458	13.741
11	BOD	5	0.100	7.254	145.08	14.508
12	SO ₄	150	0.005	42.84	28.56	0.142
13	Alkalinity	120	0.006	218.5	182.083	1.092
14	Nitrate	45	0.016	29.77	66.155	1.058
15	COD	20	0.025	8.444	42.222	1.055
$\sum W_n = 0.898$ $\sum q_n W_n = 82.357$						
$WQI = \sum q_n W_n / \sum W_n = 91.71$						

Table 7: Calculation of Water Quality Index in Summer Season

Summer Season						
S. No.	Parameters	Standard Value (S_n)	Unit Weight (W_n)	Observed Values	Quality Rating (q_n)	Weighted ($W_n q_n$)
1	pH	8.5	0.083	8.94	129.33	10.734
2	EC	300	0.002	863.5	287.83	0.5756

Table 7: Contd.,

3	Turbidity	10	0.010	7.388	73.88	0.7388
4	TDS	500	0.001	650.1	130.02	0.1300
5	Hardness	300	0.471	408.8	136.26	64.181
6	Fluoride	1.5	0.002	1.276	55.20	0.1104
7	Calcium	75	0.009	61.55	82.06	0.7385
8	Magnesium	30	0.024	17.16	57.20	1.372
9	Chloride	250	0.003	193.4	77.36	0.2320
10	DO	5	0.141	5.325	103.50	14.594
11	BOD	5	0.100	6.066	121.32	12.13
12	SO ₄	150	0.005	63.13	42.086	0.2104
13	Alkalinity	120	0.006	308.5	257.08	1.5424
14	Nitrate	45	0.016	40.77	90.60	1.4496
15	COD	20	0.025	14.88	74.40	1.8600
$\sum w_n = 0.898 \quad \sum q_n w_n = 110.59$						
$WQI = \sum q_n w_n / \sum w_n = 123.15$						

RESULTS AND DISCUSSIONS

Analytical results obtained for different study parameters from different sampling locations in different seasons of the year 2012-2013 are summarized in Table 4. Permissible limits and recommended agencies are described in Table 3. The results obtained season wise are discussed below.

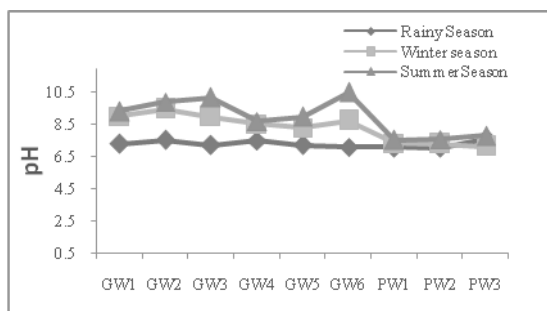


Figure 2: Variations of pH in Different Seasons

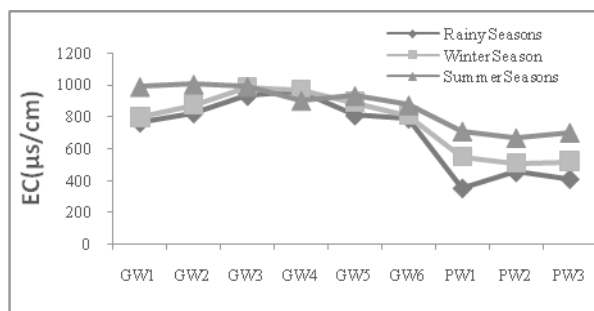


Figure 3: Variations of EC in Different Seasons

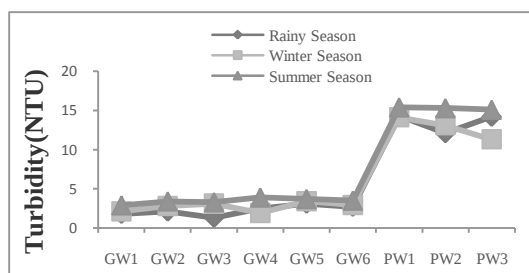


Figure 4: Variations of EC in Different Seasons

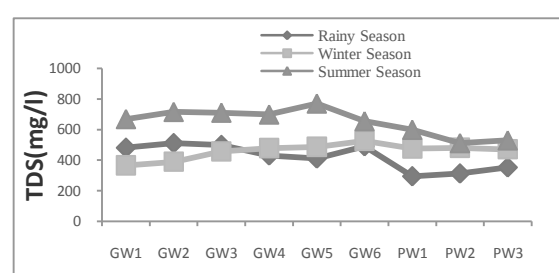


Figure 5: Variations of TDS in Different Seasons

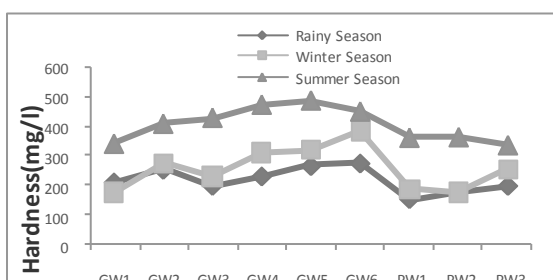


Figure 6: Variations of Hardness in Different Seasons

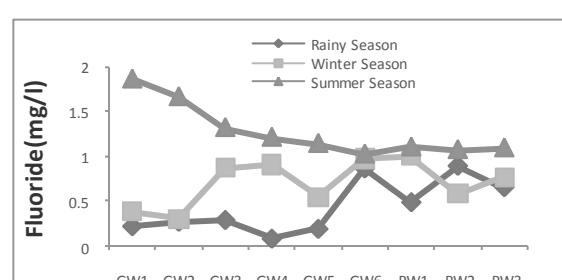


Figure 7: Variations of Fluoride in Different Seasons

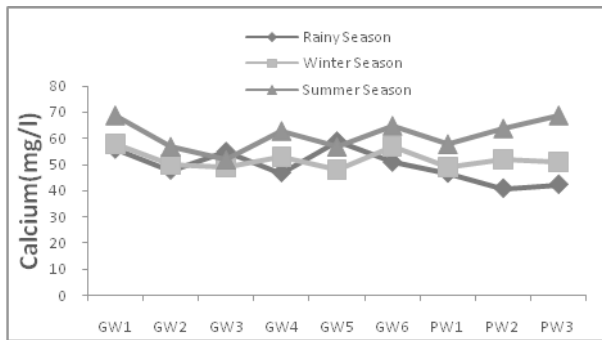


Figure 8: Variations of Calcium in Different Seasons

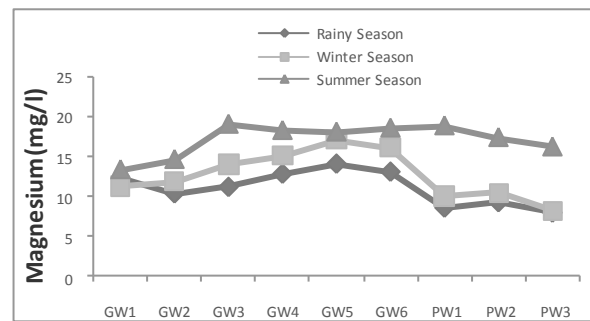


Figure 9: Variations of Magnesium in Different Seasons

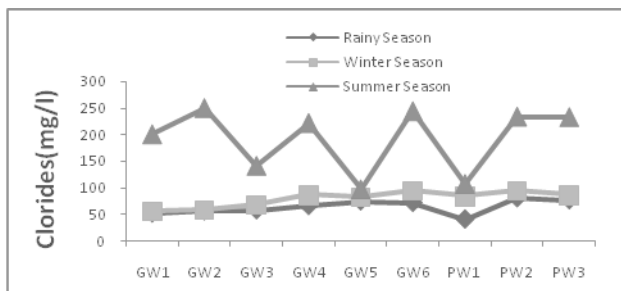


Figure 10: Variations of Chloride in Different Seasons

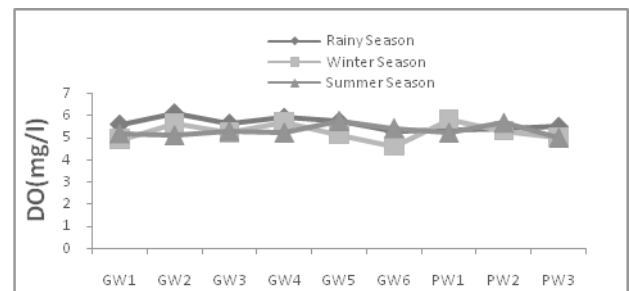


Figure 11: Variations of DO in Different Seasons

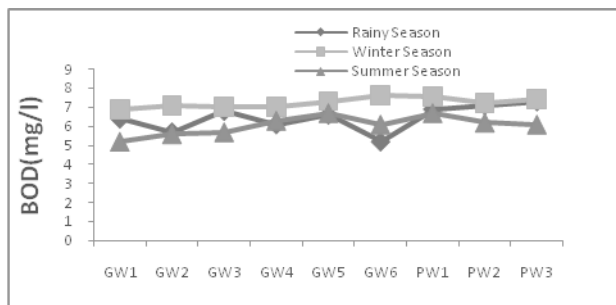


Figure 12: Variations of BOD in Different Seasons

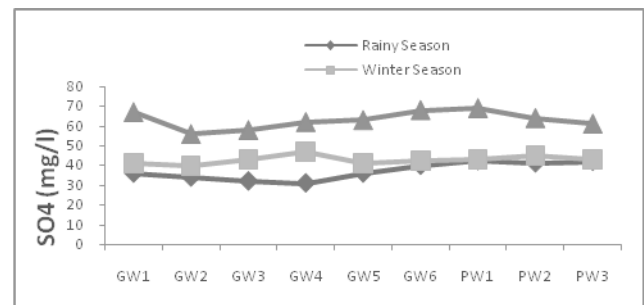


Figure 13: Variations of Sulphate in Different Seasons

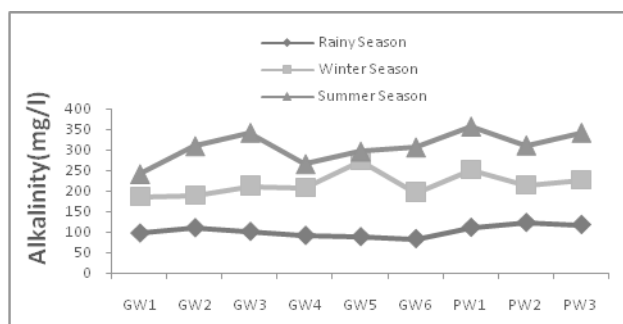


Figure 14: Variations of Alkalinity in Different Seasons

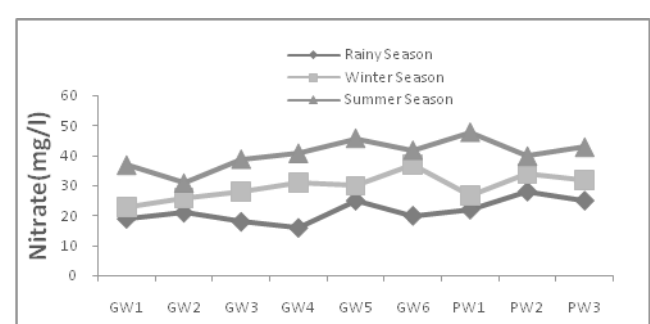


Figure 15: Variations of Nitrate in Different Seasons

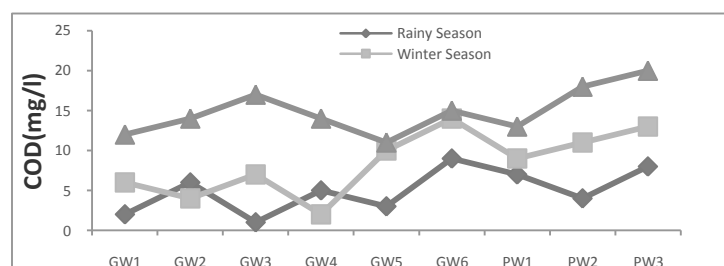


Figure 16: Variations of COD in Different Seasons

pH- pH value of natural water changes due to biological activity and industrial contamination. pH of the samples was in the range from 7.04 to 10.5 so that alkaline in GW1 to GW6 in winter and summer season. Higher pH value imparts bitter taste.

EC- EC indicates that the content of soluble and high conducting salts present in the water sample. Here EC of all samples in variable seasons in the range of 410 to 1004 $\mu\text{S}/\text{cm}$ from different locations with mean values 698.8 to 863.5 $\mu\text{S}/\text{cm}$. The mean value of EC is above the permissible limit.

Turbidity- Turbidity of the samples in different seasons in the range of 1.8 to 15.4 NTU with mean value 6.01 to 7.38 NTU. The mean value of turbidity is within permissible limit.

TDS- TDS of the samples in different location in the range of 294 to 770 with average value 419.5 to 650.1. In summer seasons the value is above the permissible limit, while rest of the samples have within the highest permissible limit. The high value may be due to the addition of solids from run off water, sewage, industrial effluents and other domestic effluents directly to the pond.

Hardness- Hardness of the samples in different location in the range of 152 to 490 with average value 218 to 408.8. In summer seasons the value is above the permissible limit, while in winter Gw4 to Gw6 is slightly high rest of the samples have within the permissible limit.

Fluoride – Fluoride concentrations in the range of 0.07 to 1.87 with the mean value of 0.431 to 1.276. Thus fluoride concentration is below the permissible limit.

Calcium & Magnesium- The average value of calcium was 49.59 in rainy seasons, 51.88 in winter and 61.55 in summer seasons. While magnesium was 10.96 during rainy, 12.62 during winter and 17.16 during summer seasons. The average value is within the permissible limit.

Chloride – The high concentration of chloride is considered to be an indication of pollution due to high organic waste of animal origin. Chloride mean values obtained in rainy seasons 65.16, winter 79.66 and in summer season 193.4 shows within the permissible limit.

DO- The average value of DO in rainy seasons was 5.59, 5.24 in winter season, while 5.32 in summer season. This shows that the DO above the permissible limit is good for health.

BOD- The average value of BOD in rainy seasons was 6.45, 7.25 in winter season, while 6.06 in summer season. Result indicates the mean value was above the permissible limit.

Sulphate- Sulphate ions do not affect the taste of water, if present in low concentrations. The sulphate ion concentration in rainy seasons was 37.17, 42.84 in winter season, while 63.13 in summer season. Result indicates the mean value was below the permissible limit.

Alkalinity- Alkalinity is an important if it is less than 100 ppm is desirable for domestic use; however in large quantities it imparts bitter taste to water. In the present investigation alkalinity was found in rainy seasons was 103.4, 218.5 in winter season, while 308.5 in summer season. Result indicates the mean value was above the permissible limit.

Nitrate- Nitrate ions rainy seasons was 21.55, 29.77 in winter season, while 40.77 in summer season. Result indicates the mean value was below the permissible limit.

COD- The average value of COD in rainy seasons was 5.0, 8.4 in winter season, while 14.88 in summer season. Result indicates the mean value was below the permissible limit.

Groundwater Quality Assessment- Water Quality Index out of nine samples was computed for the study area in the rainy, winter and summer season are presented in Table 5,6 and 7 respectively. The computed WQI for rainy season indicate that the overall WQI was 74.00 as compared to winter season 91.71 and summer season 123.51 respectively. The high values of WQI have been found in summer season and lower value in rainy season. All the seasons the ground water quality is found good in compare to pond water. The high value of WQI in summer season is because of high concentration of TDS, calcium, magnesium, alkalinity, hardness and EC in ground water. Water quality of some samples tends to poor quality during summer season and winter season.

CONCLUSIONS

The study has been conducted in Sirsakai village of Bhilai-3 city in Chhattisgarh for measuring quality of ground water and pond water. The samples shown that the pH of the ground water was above the permissible limit as prescribed by Indian Council for Medical Research and Bureau of Indian Standard. Electrical conductivity values are above the permissible level. The results show that some parameters shown higher values in summer and winter seasons and which don't within the limits of standards and also water quality index. So highest priority should be given to water quality monitoring and there indigenous technologies should be adopted to make water fit for domestic, bathing and drinking purpose after treatment.

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